Sensor checks pipeline integrity

Smart Mater. Struct. **17,** 015006 (2008)

Researchers in Naples, Italy, have shown that optical-fibre sensors can be used to monitor the structural integrity of a pipeline, as well as the deformations of the rock or soil surrounding the pipeline. They found that, by measuring normal strain using stimulated Brillouin scattering along three longitudinal directions running down the pipeline, they could measure the amount of pipeline dislocation and its direction.

Other researchers have shown that it is possible to use a distributed Brillouin fibre sensor system to measure large compressive strain and detect pipeline buckling. Romeo Bernini from the Institute for Electromagnetic Sensing of the Environment and his colleagues from the Second University of Naples, however, have gone one step further and shown that it is also possible to retrieve more detailed information about the pipeline dislocation. “This is very important in order to realize a real-time intelligent monitoring system useful for early detection of events eventually leading to pipeline rupture,” he says.

In their laboratory, Bernini and his colleagues attached three fibres to the circumference of a test pipeline, reciprocally displaced by 120°. “We have focused on improving the accuracy and the spatial resolution of the Brillouin fibre sensor,” says Bernini. “We developed a measurement set-up that worked in the frequency domain and used synchronous signal detection. We also devised algorithms that are able to process the optical signals acquired in the frequency domain.”

The group is currently working to improve the performance of the sensor even further. In particular they plan to extend the maximum sensing length, which is currently limited to a few tens of kilometres.

Dynamic analysis of the impact of traffic

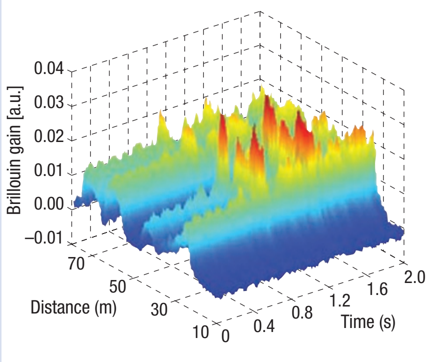
Smart Mater. Struct. **17,** 015003 (2008)

Researchers in Canada have used embedded fibre sensors to monitor impact waves in concrete slabs resulting from highway traffic.

Xiaoyi Bao and colleagues from the Universities of Ottawa and Sherbrooke, monitored distributed impact waves due to traffic in real time, using stimulated Brillouin scattering. This type of sensor system can usually only measure static temperature and strain, because the system response time is in the range of minutes.

“We used the polarization dependence on the stimulated Brillouin scattering in the fibre to detect the sudden birefringence change induced on the sensing fibre,” said Bao. “This allows us to demonstrate the impact wave response with a distributed dynamic sensor for the first time.”

The concrete slabs were reinforced with fibre-reinforced polymer, but this has a serious drawback because impact damage substantially reduces the compressive strength. Impact damage is hidden and cannot be detected by visual inspection or standard strain monitoring.



The sensing fibre used for impact-wave detection was attached to fibre-reinforced polymers, which were embedded in eight full-scale continuous reinforced concrete slabs on Highway 40 in Montreal. The data (pictured) showed peaks in the Brillouin scattering that have a height proportional to the stress in the concrete slab. High peaks represent trucks and lower peaks represent cars.

“Our current distributed dynamic sensor system requires access to the sensing fibre from both ends; the next phase of the research is to make a sensor system with one-end access,” said Bao. “We also need to improve the signal-to-noise ratio of the sensing system to reduce the signal processing time further and increase the measurable frequency range.”

A new parameter

J. Opt. Soc. Am. (in the press)

Researchers in Denmark are proposing the adoption of a new approach for characterizing long-period gratings in photonic-crystal fibre sensors.

Lars Rindorf and Ole Bang from the Technical University of Denmark in Lyngby, have shown that although Bragg gratings in photonic-crystal fibre are best characterized in the usual way, that is, by the sensitivity (defined as the resonant wavelength shift divided by the resonant wavelength), long-period gratings are better characterized by their quality factor (defined as the resonant wavelength shift divided by the full-width at half-maximum of the resonance dip). Rindorf and Bang explain that formulae used for standard optical fibres do not apply for photonic-crystal fibres, as these fibres are typically made of two materials, such as silica glass and air.

By considering the properties of each material separately, the researchers found rigorous formulae that apply to photonic-crystal fibres. They also identified a term for temperature and strain sensing that was previously unaccounted for.

Finding hydrogen leaks

IEEE Photon. Technol. Lett. **20,** 1041–1135 (2008)

A leak detector that can detect a 1% concentration of hydrogen in air with a response time of less than one second has been developed by researchers in Mons, Belgium. The team, from Materia Nova and Faculté Polytechnique de Mons, used fibre Bragg gratings covered with a catalytic sensitive layer. This was made from tungsten oxide powder doped with platinum, which induces a temperature elevation around the fibre Bragg gratings in the presence of hydrogen in air.

In the past, fibre Bragg gratings covered with palladium have been widely investigated for hydrogen sensing, where the sensing mechanism is based on the swelling of the palladium coating, resulting in a stress on the grating. In practice, the palladium-coated sensors suffer from a variety of problems, including a long response time and measurements affected by hysteresis.

The Mons team claims to have solved these problems with its new sensor design. In the presence of hydrogen in air, the sensitive layer takes part in an exothermic reaction, and the increase in temperature around the fibre Bragg grating is measured through a shift in its central wavelength.

The researchers have demonstrated that a good sensitivity is obtained whatever the relative humidity level of the air. They also showed that the grating length does not influence the temperature delivered by the chemical reaction, and that the sensor has a linear response to varying hydrogen concentrations. This linear response is reversible, so there is no need to recondition the sensor after hydrogen detection. It is also compatible with frequency multiplexing and can be used in quasi-distributed sensors.